Barriers faced by new-adopter of Last Planner System®: a case study

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Abstract

Purpose – Documented evidence supports the improvements resulting from the use of the Last Planner System® (LPS) as a lean construction technique; however, several barriers to the implementation of the technique have been identified. The purpose of this paper is to evaluate the implementation process of LPS by a project team that is transitioning from the traditional planning and control to LPS on a typical commercial project. The paper compares the adopted implementation process with that of the recommended best practices and identifies the overlaps and variances.

Design/methodology/approach – An in-depth case study was conducted to accomplish the specific objectives: document the process of LPS implementation in detail; identify the overlaps and variance from the recommended practices; and investigate the causes for variance from the recommended practices. The authors used direct observations, document investigations and semi-structured interviews with key project participants to gather data. Constant comparison and content analysis were used as data analysis method for this study.

Findings – The paper identified critical barriers to the implementation process of LPS in the case study project, which are supported by existing literature and are considered typical of project teams that are new adopters and transitioning to the implementation of LPS.

Research limitations/implications – Based on a single case study, the outcomes may lack generalizability. However, similar findings of existing literature and evaluations by the project personnel substantiated the findings of the study.

Originality/value – The study attempted to conduct a systematic investigation on the implementation process of LPS, which is a less investigated topic. The paper draws attention to the major barriers experienced while adopting LPS in the case study project and suggested possible ways to address similar issues in the future. The barriers experienced by the case study project are typical of project teams who are new adopters and transitioning to the adoption of LPS, process and have the potential to be alleviated through the recommended practice implementation and process maintenance strategy.

Keywords Scheduling, Case study, Construction planning

Paper type Case study

Introduction

Increasing adoption of lean construction practices has allowed for many organizations to realize performance improvements in terms of productivity, project budget, schedule reliability and improved safety (Hamzeh and Bergstrom, 2010; Koskela *et al.*, 2010; Hamzeh, 2011; Fernandez-Solis *et al.*, 2013; Aziz and Hafez, 2013; Lindhard and Wandahl, 2013). The Last Planner System® (LPS) for production planning and control is one of the lean construction techniques that have been of particular interest within the industry since the 1990s. It has been "successfully implemented in construction to increase the reliability of planning, improve production performance, and create a predictable workflow" (Hamzeh *et al.*, 2009). While many organizations are implementing such tools, scholars have reported multiple barriers and constraints in the process of implementation (Alarcon *et al.*, 2008; Porwal *et al.*, 2010; Fernandez-Solis *et al.*, 2013; Tiwari and Sarathy, 2012).

With the proclaimed benefits of LPS well documented, there has been a steady growth in the adoption of the technique among the construction companies. LPS is well described in the literature (Viana *et al.*, 2010) that facilitates in the adoption of the technique, frequently assisted by in-house lean champions or outside coaches. As the project teams go through the transition

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of adopting LPS in place of the traditional project planning and control, they are expected to follow the recommended best practices. Most studies on LPS so far have focused on the effectiveness of the implementation of the technique and its impact on project performances (Koskenvesa and Koskela, 2005; Salem *et al.*, 2006; Hamzeh and Bergstrom, 2010; Porwal *et al.*, 2010; Hamzeh, 2011; Lindhard and Wandahl, 2013). However, there is lack of systematic investigation on the process of implementation of LPS by new adopters. A case study approach was adopted for the current study to investigate the implementation of LPS on a commercial project and how its implementation and use on the study project varied from the recommended best practices. The findings of this study will contribute to the understanding of the process of implementing LPS with lessons learned and the barriers faced by the study project to benefit the future adopters of LPS. The authors did not attempt to evaluate the efficacy of the recommended best practices for the implementation of the LPS as part of this study.

The paper is divided into the following sections: literature review, goal and objectives of the study, research methods, findings and discussions. The Literature review section provides a brief background about lean construction and elaborates the benefits of LPS with few cautions identified by existing literature. The subsequent sections define the overall research goal of identifying the specific objectives for this study. The method adopted to accomplish the objectives is described in detail followed by summarizing the findings of the study, and the discussions based on the findings.

Literature review

Since first named in 1993 by the International Group for Lean Construction (IGLC), "lean construction" has been gaining popularity within the architecture, engineering and construction industry. Its rise in popularity is largely driven by increased awareness of lean techniques and the researched benefits. A number of researchers: Ballard (Ballard, 1994, 1997, 2008; Ballard and Howell, 2003; Ballard and Tommelein, 2012) Howell (Howell, 1999; Howell and Koskela, 2000; Ballard and Howell, 2003, 2005), Koskela (Koskela, 1997; Koskela *et al.*, 2002; Koskela and Huovila, 2010; Koskenvesa and Koskela, 2012) and many more have been contributing to the understanding of lean construction, its techniques, processes, benefits and constraints for several years.

There are many techniques used to achieve the goals of lean construction, addressing operational planning and control, visualization and continuous improvement. One technique that has been of particular interest since its development in the 1990s has been the LPS®, which addresses production planning and control. LPS has been defined by a number of lean construction researchers, many referring back to the definition presented by, as "a production system and control system to assist in smoothing variations in construction workflow, developing planning foresight and reducing uncertainty in construction operation." This definition has been adopted and paraphrased multiple times within the academic community with some authors presenting slightly different interpretations. Despite the various interpretations of the LPS definition, the understanding of the technique is the same. Implementation of the technique allows for the collection of key performance indicator such as Percentage Plan Completed. Koskela *et al.* (2010) have described PPC as "a measure of the proportion of promises made that are delivered on time." It is calculated based on the weekly work plan (WWP); the number of activities planned for; and the number that was completed by the work team. This process attempts to ensure accountability and determines the causes of non-completion (Bortolazza *et al.*, 2005; Formoso and Moura, 2009; Hamzeh and Bergstrom, 2010; Aziz and Hafez, 2013). Below are definitions of the major terminologies used in the LPS technique:

- Master schedule: the basis for delivering the project delivery and meeting milestones.
- Phase schedule: a breakdown of the tasks within a specific timeframe undergoing a collaborative reverse scheduling approach or a "pull."

- Look-ahead schedule: a production schedule showing a four- to eight-week look-ahead through make-ready planning using constraint analyses and collaborative design of tasks.
- WWP: using the look-ahead schedule plan work for next week while reporting progress on last week. This is used to evaluate Percent Plan Complete (PPC), identify reasons for non-completion of tasks and update the next WWP accordingly.

Formoso and Moura (2009), studying a large project database including industrial, commercial and residential projects, indicated that a correlation exists between the use of LPS and project performance regarding cost and duration. The technique's use positively affected these variables within complex industrial and commercial projects. Their research exploring the impact of LPS in terms of cost and duration indicated that 81 percent of problems were predominantly internal, i.e., labor, material, equipment, design or planning related. This was based on a performance assessment of 119 projects. Planning and controls are considered internal factors, and improvements in these processes have been identified as "one of the most effective ways to increase efficiency in the construction industry" (Aziz and Hafez, 2013). For this reason, it is believed that the LPS, which aims to improve the performance of production planning and control, has the potential to be so effective. Aziz and Hafez (2013) who gathered information from several sources discussed the usefulness of the LPS in relation to managing construction processes, controlling and smoothening workflow variation, as well as monitoring plan efficiency practices. In their report, they also mentioned that "companies utilizing the LPS have been able to maintain projects on time and the budget, as well as having a stress-free production planning and control process" (Aziz and Hafez, 2013).

Koskela *et al.* (2010) in their comparison of LPS and Critical Chain (another production management tool) determined that where some methods experience benefits associated with simple schedule reduction, the LPS achieves more with its continuous improvement commitment, increased plan reliability, productivity and reduced variability leading to cost savings. The nature of the LPS and its continuous improvement feature also allows for a deeper understanding among the project team through their investigation of reasons for the non-completion of tasks (Koskela *et al.*, 2010). Many researchers also claimed that LPS, through its collaborative approach, encourages teamwork, enables proactive involvement, promotes participation, transparency and improves communication and coordination (Song *et al.*, 2008; Koskela *et al.*, 2010; Seppänen *et al.*, 2010; Porwal *et al.*, 2010; Tiwari and Sarathy, 2012; AlSehaimi *et al.*, 2014). Priven and Sacks (2013) stated that LPS when used on a hospital expansion project "helped the team come up with a process that was comprehensive, transparent, flexible and collaborative and eliminated overproduction." Its use on this project further demonstrated the technique's ability to be used on a range of projects and maintain its success. Mossman (2013) also outlined LPS's ability to be effective on small and large projects referencing projects such as the $6.5bn London Heathrow Terminal 5 and the $600m North Staffordshire Hospital.

Few researchers have cautioned that regardless of the benefits of LPS, in order to recognize substantial improvement, the planning and control system requires "holistic implementation." This implementation will influence the overall success of the process and its effectiveness. Hamzeh and Bergstrom (2010) had identified that the LPS is not a "stand-alone tool" to be put into operation when needed, further emphasizing the need for holistic implementation. Ballard and Tommelein (2016) insisted upon holistic implementation describing the LPS is a system of interconnected parts and "omission of a part destroys the system's ability to accomplish its functions." Other researchers have investigated LPS's implementation at different stages of a project such as during the planning/pre-construction stage, the beginning of construction and nearing completion

(Tiwari and Sarathy, 2012; AlSehaimi *et al.*, 2014). Although it has been recognized that effective early implementation is necessary to see the most benefit from the use of LPS, Aziz and Hafez (2013) drew attention to a study by Fernandez-Solis *et al.* (2013), which demonstrated the improvements seen when LPS was implemented nearly six months after the project began. A similar situation was seen by AlSehaimi *et al.* (2014) where the LPS was introduced after the construction phase began. Both projects within the study showed improvements despite the late adoption of the technique.

The successful implementation and use of the LPS on several construction projects have shown its ability to "increase the reliability of planning, increase production performance and improve workflow in design and construction operations" (Hamzeh and Bergstrom, 2010). However, the need for effective planning has been recognized as a necessity as researchers have noted poor implementation planning as a major barrier to LPS being effective. Tiwari and Sarathy (2012) have added that there is also a need for discipline and commitment from all team members and many have stated the importance of participants "buy-in" to the process (Koskenvesa and Koskela, 2005). It has been said that due to an emphasis on teamwork and integration, some individuals may experience a loss of independence and feel threatened by the changes that come with lean implementation. Hamzeh and Bergstrom (2010) stated that the key is "preparing them to be willing to learn, to work better, and strive for continuous improvement," suggesting that failure to realize the need for organizational change and a sound plan for LPS implementation are main causes for failed implementation.

More recently, researchers have begun to monitor how the implementation of the LPS has improved as it increases in popularity throughout the industry. Daniel *et al.* (2015) have reported an increase in the implementation of the LPS while analyzing 57 case studies published through the IGLC. Researchers found that over the years the reported use of various LPS elements has increased; however, full implementation remains out of reach for many organizations (Daniel *et al.*, 2015; Dave, Hämäläinen, Kemmer, Koskela and Koskenvesa, 2015).

Research goal and objectives

The goal of this study was to evaluate the implementation of LPS by a project team who is new adopter, specifically how the technique is being adopted to replace the traditional project planning. The following specific objectives were identified:

- Objective 1 – develop a baseline understanding of the best practices for the implementation of LPS;
- Objective 2 – document the current "version" of the LPS being used in the study project and compare this process to the baseline created; and
- Objective 3 – recognize the overlaps and variances between the two processes and explore possible remedies to reduce any barriers and constraints being experienced.

Research method

To fulfill Objective 1, the "scan, skim, map" technique was used to preview, select and organize literature for review. Before the initial search on the databases, search criteria were developed which specified the timeframe and keywords. Ultimately, the literature survey was limited to articles that featured the words/phrase "last planner," "lean pull planning," "pull planning," "lean scheduling," "lean construction scheduling" and "Last Planner System" within the article or abstract. The range was further limited to those published within a specific timeframe narrowing the search to the last 15 years. The process map for the LPS implementation based on best practices is shown in Figure A1.

For Objectives 2 and 3, a case study approach was adopted for this study. A single case study was conducted in which the authors observed and documented the use of LPS by the project team, which is new adopter over a period of six months. The project for the case study, selected on a convenience basis, was a new five-story educational building with a basement level located in one of the state universities in the Southern Region of the USA. The primary superstructure of the building is of concrete with a light gauge metal structure for the roof. The exterior skin is of brick veneer and cast stone. The size of the project is approximately 250,000 square feet with a budget of around $100m.

The observations were conducted to understand the process of adoption of LPS and its effectiveness. Semi-structured interviews of the key project personnel were conducted to allow for discussion pertaining to the "how" and "why" of these processes and provide reasoning (see Appendix 2 for the questions used in the interview). The interview process along with the questionnaire was approved by the Institutional Review Board of Research with Human Subjects. Interviews were conducted with key personnel from the case study project, i.e., the scheduler, the lead superintendent and the project managers of major trade contractors (Table I). WWP sessions and Percentage Plan Complete evaluations were observed during the period. Information from these sessions was collected to map the process used in the case study project and compared to the suggested best practice approach gathered from current literature.

Interviews with the superintendent were used to gain a greater understanding as well as triangulate the information gathered from interviews held with the scheduler and the direct observations of the authors from the pull-planning sessions. In addition to interviews with the project team, interviews with the PMs of major trade contractors were conducted. They had varied levels of experiences of using the LPS in past projects as well as for their own organizational planning processes. The objective of these interviews was to gather the trade contractors' perspectives on the technique's use on the case study project and discuss their experiences with the technique on projects in general.

The process of PPC evaluations was observed during weekly review style sessions where a call-out method was used by the superintendent to assess the tasks completed by the responsible persons (trades). Details of the process were further discussed in follow-up meetings with the scheduler and superintendent to ensure the accuracy of interpretation.

Interviewee	Topic of discussion
Project scheduler	1. Background information on the typical process used by the project team in the planning and pre-construction phase 2. Details of the previous methods for tracking, updating and maintaining the schedule a. Reason for changing the "old way" b. Issues and constraints 3. Current process used to conduct pull-planning and WWP sessions, PPC evaluations a. Explanation of authors' observations 4. LPS implementation approach a. Barriers/constraints experienced
Superintendent	1. PPC process used a. Experience with the process, its implementation, effectiveness, barriers and constraints 2. Future use, lessons learned
PMs of trade contractors	1. LPS knowledge and experience a. Experience with the process in general, past projects, implementation, strategies, barriers and constraints 2. Case study-specific experience a. Effectiveness, learning curb, other trades experiences and barriers and constraints

Table I.
Schedule of interviews conducted for data collection

The process map of LPS implementation at the case study project created by the authors based on the observations and interviewees was next compared with the best practice process map created based on literature review to identify the overlaps and the variances. The authors substantiated the outcomes of the comparison with the scheduler and the superintendent of the case study project to evaluate the findings. Follow-up discussions with the PMs of the trade contractors reinforced the findings of the authors and facilitated the formulation of the recommendations.

Findings

The initial interview with the scheduler allowed for the construction of the case study process map. The map shows several steps where the schedule was refined using updated information, the experiences and expertise of different personnel including potential trade partners. A master schedule was produced after a final adjustment using information from post-bid meetings. This information was gathered to provide a clear understanding of a typical schedule development process that varies from contractor to contractor. The project scheduler used a commonly used scheduling software and standard procedures outlined by the organization for the schedule development and maintenance throughout the project.

Based on interviews and observations, the authors learnt that the major elements of the LPS that were utilized in the case study project were master schedule and WWP, while phase schedules and look-ahead schedules appeared to be creating some difficulty, which is consistent with the findings of Daniel *et al.* (2015) and Dave, Hämäläinen and Koskela (2015) both expressing that many organizations struggle to utilize all LPS elements.

Planning process of the case study project

The pre-construction planning information was used within the LPS once construction phase had started. Figure A2 outlines the process of pull planning as it was utilized in the case study project. Leading into the construction phase of the project, the master schedule was used to identify key milestones for the pull-planning sessions. Although it has been suggested that "the first step in pull planning is to co-create with the team a description of the milestone from which to pull" (Ballard and Tommelein, 2016), the superintendent briefly described the milestones. These milestones were used to draw attention to a particular timeframe for future work. The project team including the superintendent and trade partners then worked together to detail the tasks necessary to reach the milestones. Starting from the future date they worked their way back through the process to the current time. This was usually a long process as there was lot of discussions among the team members. Each member had their own sticky note with the color representing their trade. They then arranged these sticky notes on large boards, each specific to a task, with information related to location, manpower and duration.

Once a pull-planning session was complete, the scheduler took the information from the boards and transferred those into the digital document within standard scheduling software. This updated schedule based on the trade contractors' commitments made in the pull-planning session was then distributed to the project team: subcontractors, superintendents, trades foremen, etc., detailing the project status, what tasks were being performed, expected completion of the tasks and future work.

PPC meetings were conducted to review the previous weeks' successes and future tasks. During this fast-paced review, the superintendent led the sessions making their way through each task on the board, calling out the building, area and task details while the relevant trade contractors confirmed the tasks as complete or not. Activities that were planned but not completed were questioned further and the trade provided reasoning for non-completion and sometimes provided an estimate of when those would be completed.

Control process of the case study project

In the past, the scheduler of the case study project relied on a system that allowed the foremen from each trade to provide a progress report which was used to update the master schedule. Unfortunately, this method left greater room for tracking error. Trades would show their progress in the form of a Gantt chart they had produced using Excel, often using different terminology, breaking out tasks in their own way and sometimes providing insufficient information for the scheduler to accurately track the project. This method presented its own set of challenges as the scheduler was left to make assumptions while interpreting what was being shown and the intention of the trade. Over a period, since the beginning of the case study project, the team had transitioned to what may be described as "variations" of the LPS. This transition period, where elements of the LPS appeared to have been introduced, has been identified in existing studies as partial implementation or incremental introduction (Koskenvesa and Koskela, 2005; AlSehaimi *et al.*, 2014). During the transition to reach full implementation, a number of methods for effectively tracking progress had been tried and tested. Using WWP, resulting from pull-planning sessions and look-ahead schedules, a new tracking method had emerged.

Once information from the pull-planning boards was entered into the master schedule within standard scheduling software, a printed document was created and distributed to the team members. This document showing a form of look-ahead schedule was given to the superintendent. Due to the complexity of the project, there were multiple superintendents each in charge of specific building areas. Using this document, the project team could verify the accuracy of the information and provided progress reports. The document showed the baseline schedule with start and finish dates and task durations. Additionally, the superintendents could indicate the actual start and finish or estimated finish for tasks that were ongoing or showed variances. This information was then entered back into the standard scheduling software to show the status of the project. The documented schedule changes translated to changes on the pull-plan boards and shifted milestones according to the verified information (see Figure A2).

Process used in case study project vs best practice process

Comparing the best practice process map created with the case study process map (see Figures A1 and A2) there are some clear differences. Setting aside the differences in terminologies, the case study project appears to be lacking the implementation of key aspects of LPS. Based on the data collected, the authors noticed the lack of the following aspects:

- While conducting PPC evaluation, there was no formal root-cause analysis, or corrective action plan created when a task could not be completed (Figure A1).
- Partial implementation of look-ahead scheduling techniques: the look-ahead plans appeared to be prepared by the project team directly from the Master Plan, leaving out the phase planning function. In addition, constraints were outlined as a list for an upcoming period of time rather than looking at each task individually and identifying constraints on a task-by-task basis. Additionally, the "make-ready" function was not practiced.

The authors used a fishbone diagram (Figure A3) to further explore the reasons for partial implementation of LPS in the case study project and determine the possible root causes. The diagram categorizes the underlying causes into four areas: technology (the computer applications being used), people/manpower (members of the project team including subcontractors and trades), management (project team leaders, managers and supervisors) and method (the processes used). Each category has a number of primary causes (shown by horizontal lines) and secondary causes (shown by diagonal lines) that stem from those primary causes. Not all causes are a direct result of the project team. In terms of technology, the lack of a currently available software that meets their specific needs is out of their control. However, the team is able to maintain software consistency and ensure members use the same program allowing for easier integration. It was noted that members of the team use different software depending on their own comfort and skill levels.

The diagram identifies that the method currently used was due to the lack of familiarity with the new system and its transition. As for implementation strategy, the method being used in the case study project is unclear, and appears to lack standardization and planning. This lack of clarity is seen again in management and people/manpower. Both people/manpower and management share a primary cause of attitude, the lack of "buy-in" to the new way, familiarity with the "old way" and not seeing the benefits. As well as the lack of clear process and inadequate training these two categories are the main causes for the partial implementation of the technique. The attitude of both management and personnel could be the result of inexperience with the new method and over time may change as the team becomes familiar with the techniques and their benefits. Without clear processes set out by management, personnel are unable to confidently take the steps necessary to implement the technique and see its benefits.

Discussion and recommendations

Based on the observations, interviews and in the spirit of continuous improvement, several opportunities were identified for improving the process of LPS implementation in the case study project. Some areas were more vital than others but none appeared to be new. Many of the barriers discussed in existing research appear to be present in some form within the case study. Given the emergent state of the LPS within the case study project team, many of the barriers observed are considered typical for new adopters:

- Incomplete PPC process – the project team was clearly identifying causes for the non-completion of tasks; however, there was no root-cause analysis or corrective plan. According to previous studies "having reasons for the lack of task completion was experienced useful, and it was seen to contribute to the elimination of problems" (Koskenvesa and Koskela, 2005). However, based on the observations and interviews with project personnel, the information for non-completion was not effectively utilized to prevent future occurrences. The trade contractors experiencing the issues provided explanations, which were recorded on the pull-planning boards using a coding system, but never used for any further analysis. There did not appear to be a formal process in place for addressing the constraints or developing an action plan despite conversations regarding how this would be addressed in the immediate future. Hamzeh *et al.* (2009) identified that the PPC process requires "incomplete tasks [to] undergo root-cause analysis to uncover the root cause for non-completion and develop preventative actions to inhibit the same failure from recurring." The PPC process was used to address the look-ahead plan and determine the changes that must be made to upcoming work. When a task was incomplete the team would address how it would be completed in the future. A consistent theme throughout the observations and interviews was the importance of analysis. The process, according to the best practice, indicates the need for tasks to be detailed in the look-ahead schedule and allow for variance analysis to occur between what was planned and what is now planned. The lack of a formal process may be seen to contribute to the project team not reaping the full benefits of PPC process.
- The underutilization of look-ahead plans – in line with the existing literature, the case study was experiencing difficulties in developing look-ahead plans. These plans, created collaboratively four to six weeks ahead, have been created directly from the Master Plan. Dave, Hämäläinen and Koskela (2015) have identified that this results in

"suboptimal plan performance." The intended process for developing these plans involved collaborative efforts from the project team and the trade contractors to identify the most appropriate sequence and analyze the logic while identifying individual task constraints and developing a backlog of tasks for future work. Although the project team visually displayed the constraints that the team had identified, the development of a "make-ready" backlog appeared to be missing. It is worth noting in the case study project that the Master Plan underwent a collaborative planning effort in the pre-construction phase of the project which might have provided some reasoning for the reduced collaboration and sequence analysis during look-ahead plan development.

- Lack of guideline/standard practice for updating the schedule – this is an ongoing issue that has been referred to multiple times by researchers and construction professionals alike. Most recently, Dave, Hämäläinen and Koskela (2015) discussed the difficulties being faced when tracking and monitoring workflow and progress. Project personnel of the case study project faced this barrier weekly and the interviewees appeared to be aware of the problem with tracking progress. Within the project team, the progress reporting sheet that was presented to superintendents was a step the scheduler had taken to try and address the problem area within the LPS. However, within the project team there were no clear guidelines or best practice for updating the schedule. The process lacked an effective mechanism of transferring schedule changes and information regarding the current state of the project through the schedule levels, i.e., WWPs, look-ahead plans, phase plans and, finally, the master schedule. Researchers such as Dave, Hämäläinen and Koskela (2015) and Daniel *et al.* (2015) referred to this issue stating that the information "does not naturally flow back to the high-level plans." According to Dave, Hämäläinen and Koskela (2015), this lack of flow hinders overall production control aspects. The authors also found that the general contractor's foreman was spending an additional 2–3 h per week on subcontractors WWPs and incorporating information back into the schedule due to the lack of flow. The project team has expressed that they were unsure about "the right way" to update the schedule and effectively track changes based on the information generated in pull-planning sessions. This lack of standardization or organizational best practice presents its own risks and adds confusion as the method changes from project to project. The current method for progress reporting and updating needed to be addressed further to enable the development of formalized best practice processes that can be transferred from project to project without loss of knowledge.

- Piece meal approach to the implementation process – this method, briefly mentioned by Koskenvesa and Koskela (2005), is a structured order for the introduction of the LPS on site. In their explanation, the introduction was described as "seven parts, and a logical order for their progressive introduction on site." In more recent times the incremental implementation has been considered effective for introducing components of the LPS gradually. AlSehaimi *et al.* (2014) considered it a method that stabilizes and supports the introduction and helps to "minimize and manage resistance to change." Incremental introduction relies on a structured approach which does not appear to have been effectively outlined by the project team. Researchers have suggested that failure to effectively plan for LPS implementation is the "root of failed implementation." Further, Porwal *et al.* (2010) stated that the development of implementation strategies and training could be considered important steps in the success of LPS implementation and use. The project team had covered the training aspect; however, the implementation strategy was unclear.

Recommendations and conclusions

According to recent research, the use of the WWP meetings is "the most commonly implemented LPS element" (Daniel *et al.*, 2015; Dave, Hämäläinen and Koskela, 2015; Dave, Hämäläinen, Kemmer, Koskela and Koskenvesa, 2015). Therefore, it is not surprising that the project team began transitioning to the LPS through the implementation of weekly planning. The difficulties were with effectively incorporating look-ahead planning, root-cause analysis and continuous improvement – areas identified by Ballard and Tommelein (2016) as the less implemented components of LPS. The project team's partial implementation would not have been considered an issue had the team been able to state the next step in the implementation process. However, interviews with the project team revealed there was no understanding of the implementation strategy – what process/technique they would adopt next or when they would adopt it. The authors got the impression that the project team would attempt to suddenly use the next component of the LPS upon direction from the upper management with little to no explanation to the team members. This approach without an effective implementation strategy contributed to the impression of the trade partners about the LPS as "just another thing" they had to do. The benefit of an incremental implementation strategy to facilitate the project team understand the different components of LPS and transition from traditional project planning to the LPS was echoed through all the discussions with the project personnel.

Observations have led to the realization that the case study project team might benefit from a "champion" to lead the team in its implementation rather than the division of responsibilities among the project team. According to Soares *et al.* (2002), "a continuous effort is necessary in order to maintain and perfect the positive results obtained from the implementation of production planning and control systems." But, ambiguity of responsibilities had led to confusion about who was responsible for maintaining the system and any positive results it might be providing. A commonly mentioned barrier throughout the literature is a lack of leadership, but in this instance, the fragmented leadership rather than a lack of is believed to be a contributing factor (Hamzeh, 2011; Fernandez-Solis *et al.*, 2013). Despite the best of intentions, dividing the responsibilities among the project team for maintaining the various aspects of the system appears to be hindering the team's quest to achieve more positive results from the LPS.

The interviewees provided additional details explaining their experiences with the process and the personnel involved. As the superintendents were often the main points of contact and the leads for LPS among the project trades, it seemed appropriate that they shouldered most of the LPS responsibilities. However, given the current workload faced by the superintendents, the LPS implementation should be "led by the project manager with the support of the staff members, who are the champions of different techniques" (Salem *et al.*, 2006). Interviewees expressed, like academics, that a lean "champion" would be beneficial to the project team. Even though the project team attempted to stay true to the original intent, over time the process appeared to change as the team brought in additional personnel, and made their way through the stages of team forming. It appeared that the project team was more inclined to call out a trade for their inconsistent performance in the beginning than as the project progressed due to the development of a relationship among the project team. This further emphasized the need for a "champion" to hold the team true to the intention.

The following outlines the core recommendations put forward by the authors based on first-hand observations and multiple interviews with project personnel:

- incremental implementation strategy;
- process maintenance, i.e., refresher training and addressing the constant personnel changes on the trade partners side;
- formalized progress reporting method that better enables flow within schedule levels; and
- LPS champion to maintain and ensure the intent of the system.

Additionally, the authors have made note of secondary recommendations that due to research limitations and the focus of this paper were not able to be fully explored. Other process recommendations that may support the removal of unnecessary constraints being faced within the project team relate to inconsistency in scheduling methodology and LPS use include:

- Consistent organizational method – clearly define how areas/work will be identified, if the method has changed ensure it is made clear how it has changed and provide reasoning to the project team (building, level, area and sequence).
- Ensure pull-planning boards utilize the same breakdown, coding reference method used within the scheduling software for ease of interpretation and information transfer for updating schedule.
- Where possible, work within the means of the software and programs it communicates effectively with – it is important for consistency among the project team to utilize the same software for the same purpose, and avoid switching from one to another. Although, this may not always be possible, utilizing a single scheduling software that allows for the import and export of information needed into other programs such as Excel removes the need to manually create separate documents.

Ultimately, the case study project team appeared to address some of the practices that the LPS advocates including planning in greater detail as the work get closer, develop work plans by those responsible for performing the work and identifying and removing constraints ahead of time when possible. However, the LPS advocates making reliable promises and drive work execution based on coordination and active negotiation with trade partners and project participants, and learning from planning failures by finding the root causes and taking preventative actions. (Ballard, 2000; Ballard *et al.*, 2007; Hamzeh *et al.*, 2012; Daniel *et al.*, 2015). Both appear to be lacking within the case study project and have been identified as the primary difficulties in earlier discussions.

Despite attempts to implement the LPS fully within the case study project, it appears that effective implementation remains out of reach. This is consistent with current literature that expresses many project teams "face significant hurdles when implementing the new system" (Hamzeh, 2009). The recurrent problem facing project teams remains mostly unchanged since the beginning of LPS; the use of look-ahead planning, continuous improvement and root-cause analysis; and the collaborative aspects continue to provide some degree of difficulty (Dave, Hämäläinen and Koskela, 2015).

Members of the project team also expressed a degree of difficulty being faced with the variations in schedule due to issues outside of their control such as design changes and long wait times on RFI responses. The LPS is used for planning control and constraint identification; however, there is not a roadmap to address issues that arise from the project design team. Another area of interest that is not fully addressed within the LPS is the tracking and monitoring of schedule variations. As mentioned the project team has developed their own way of updating the schedule but the lack of process within the LPS to facilitate the free flow of information throughout the schedule is a major shortcoming of the system.

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Appendix 1

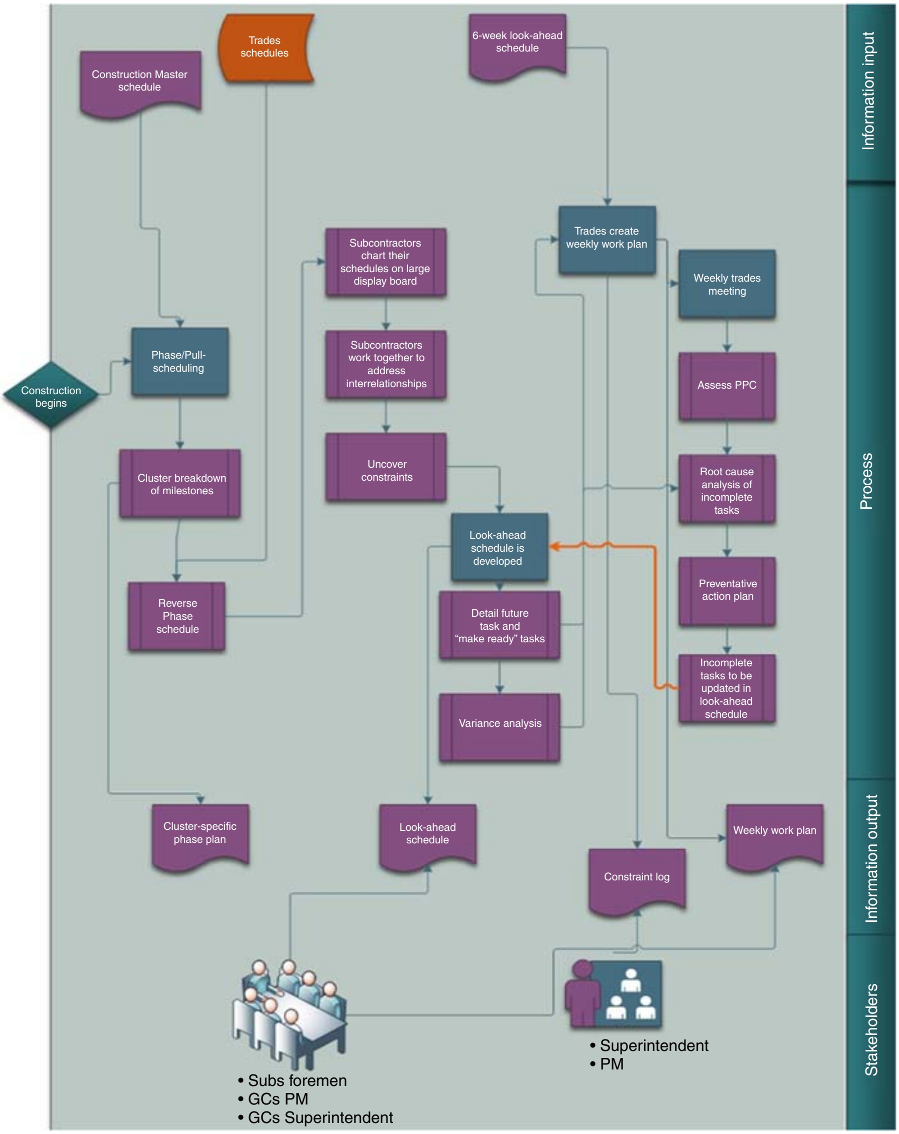

Figure A1. Recommended best practice for LPS implementation

Appendix 2. Questions used for semi-structured interviews

(1) Once the decision is made to bid for the project, how is a schedule developed?
   - Who is involved in this initial schedule?
   - How are the milestones created?
     - What are considered project milestones?
     - How are the milestones created?
     - Why are milestones important to the project?

(2) Once the company has been selected as the GC, how does the schedule develop further?
   - What is this schedule used for?
   - What process is used to refine the schedule?
   - How are the phase plans used?
   - How are the milestones used in pull planning?

(3) How are pull-plan sessions conducted?
   - What information is produced?
   - How is this information used?
   - Why is this information important?

(4) How is the schedule reviewed?
   - What is Percentage Plan Complete?
   - What is a WWP?
   - What information does this provide?
   - What happens after the PPC is done and …?
     - Changes are made?
     - No change made?

(5) Can you tell me about your experiences with the LPS?
   - Would you say you've seen benefits?
     - What are the main benefits you've seen?
   - Would this be a tool you would implement in the future?

(6) Can you tell me about your experience with the implementation of the system?
   - Has the implementation differed from project to project?

Appendix 3

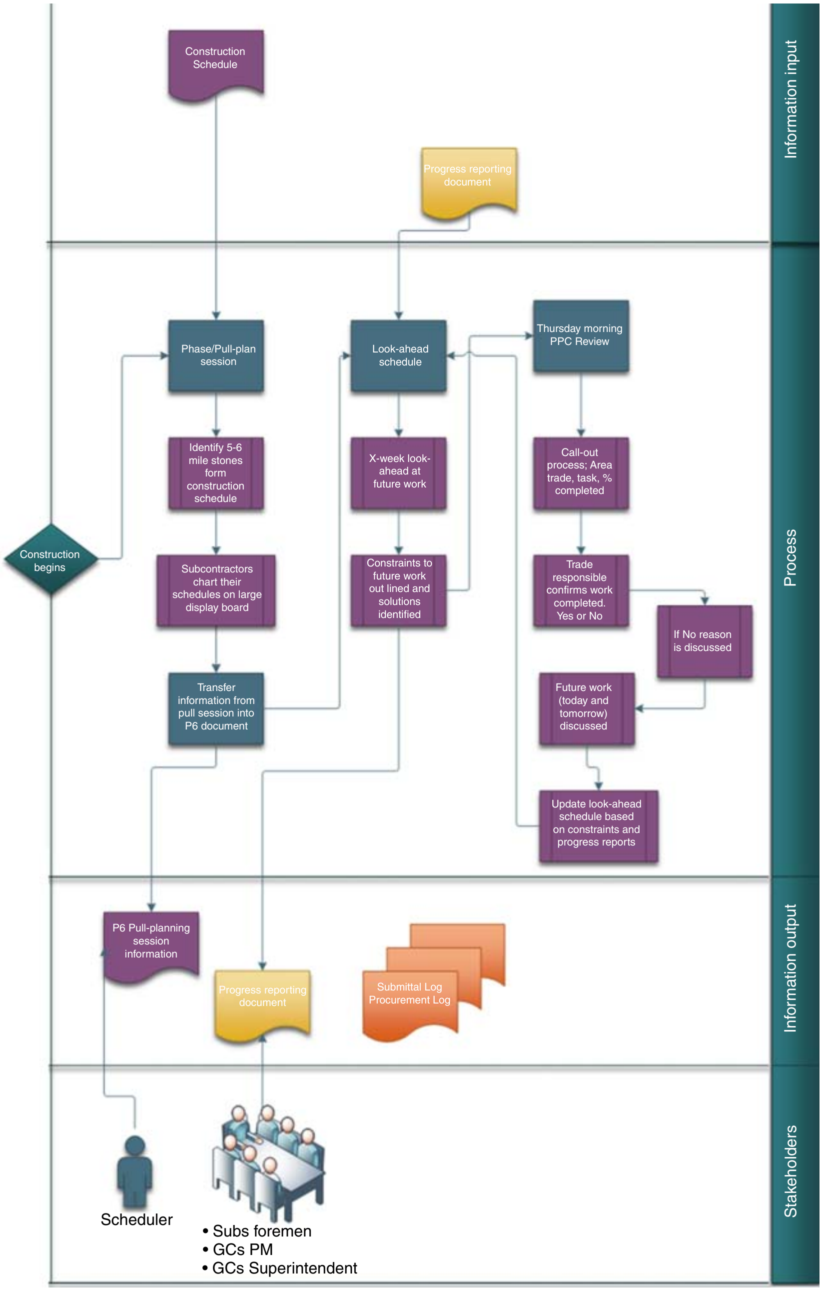

Figure A2.
Case study LPS process

Appendix 4

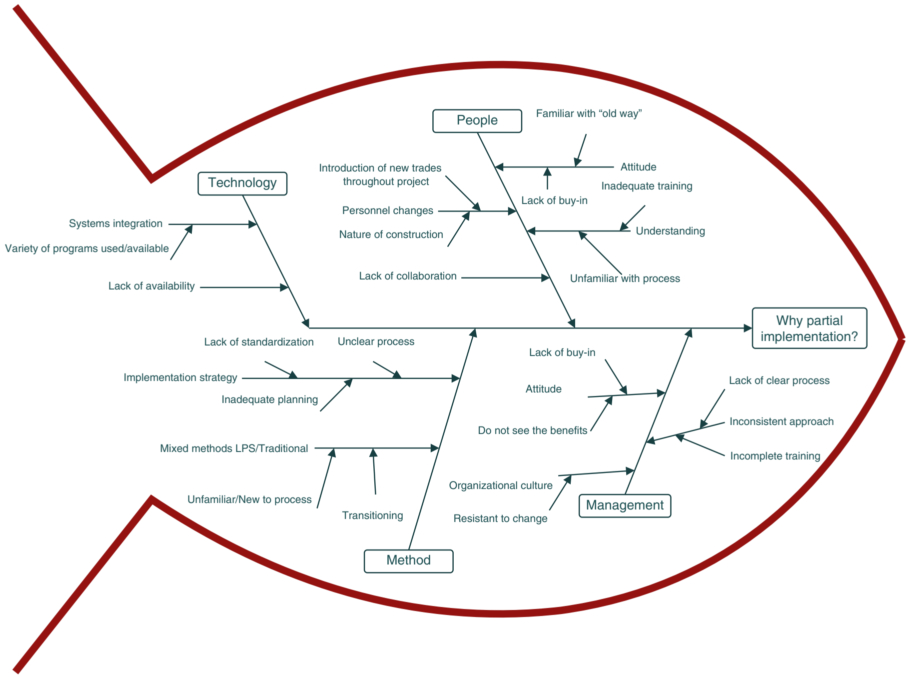

Figure A3.
Root cause analysis for partial implementation of LPS

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